research review

OAR: The Research Agency
of The United States Air Force

VOLUME III NUMBER 2 USAF ACADEMY APRIL 1964

AUGER TRANSITIONS

EDWIN J. CALLAN, Plans and Analysis Office, ARL

Some thirty years ago the mainstream of physics turned from the region of atoms to that of the nucleus. It was rather an abrupt turning, resulting from a variety of reasons. The brilliant burst of the previous decade had resulted in achieving knowledge of the fundamental structure of the atom through the Schrödinger equation, matrix mechanics, the Dirac theory, and other far-reaching concepts. Some hard-won confirmations of this structure were achieved by the discovery of the positron, by the Hylleraas wave equation for helium, and that of James and Coolidge for the hydrogen molecule--and by an understanding of spectra. But while these nuggets raised the fever to reach the lode, the machinery was not available to replace the back-breaking pick-and-shovel labor needed to mine the ore. So, with the discovery of the neutron, many moved to other streams where nuggets were more readily accessible. Work continued on the many-body problems of atomic physics, with the Hartree-Fock methods as the mainstay for obtaining wave functions, abetted by many ingenious approximation methods. But still there remain many lacunae in fleshing out the theory.

Of recent years there has been a resurgence in atomic theory, brought about by two major factors: the advent of the large-scale electronic computer; and the real and urgent needs of aerophysics, solid-state physics, chemical physics, and astrophysics, among others, for more detailed fundamental information on atomic properties, particularly for heavier atoms. Availability of the computers has allowed much of the drudgery to be passed on to them, and at rates of speed sufficient to make economic many of the desired calculations. Even yet, the picture isn't complete, and another generation or two of larger and faster computers will be needed to arrive at the goals.

Among the veins which could not be explored in depth earlier are those concerning radiationless transitions. These are important classes of transitions appearing in nuclear, atomic, and molecular theory as internal-conversion, Auger, and autoionization processes respectively (1). We shall be concerned here only with the atomic process. When an atom is ionized in a deep shell, such as by an X-ray, it tends to return to the ground state and give up its excess energy either by a radiative or a radiationless transition (Fig 1). In the former case, another electron fills the vacancy and a light

(Continued on P.3)

research review
OFFICE OF AEROSPACE RESEARCH

AUGER TRANSITIONS
Edwin J. Callan, Plans and Analysis Office, ARL.....1

SOUND AND TEMPERATURE
Dr. N. W. Rosenberg, Upper Atmosphere Physics Laboratory, AFCRL.....7

THE INFLUENCE OF HYSTERESIS ON SKIN EFFECT
John C. Corbin, Jr., Plans and Analysis Office, ARL.....8

THE IMPORTANCE OF A QUIESCENT PLASMA FOR PLASMA PHYSICS
Walter Friz, Plasma Physics Research Laboratory, ARL.....10

ULTRASENSITIVE MAGNETOMETER
Dr. Ernst R. Czerlinsky, Solid State Sciences Laboratory, AFCRL.....11

SEMANTIC SPECTRA
Rowena Swanson, Directorate of Information Sciences, AFOSR.....13

EVAPORATION OF THE SOLAR CORONA
Dr. Hari K. Sen, Space Physics Laboratory, AFCRL.....14

RESEARCH NEEDS IN MFD
Kenneth R. Cramer, Thermomechanics Research Laboratory, ARL.....16

PYROLYSIS OF FLUORINATED ORGANIC COMPOUNDS I. 1, 2-DIBROMO-1-CHLORO-1, 2, 2-TRIFLUOROETHANE AND SOME RELATED HALOGENATED ETHANE DERIVATIVES
J. D. Park, Captain R. W. Lamb, and J. R. Lacher
The Frank J. Seiler Research Laboratory.....17

ALL-PLASMA RADAR SYSTEM
Sheldon B. Herskovitz, Microwave Physics Laboratory, AFCRL....20

EXPERIMENTS IN HUMAN COMMUNICATION
Dr. Harold Wooster, Directorate of Information Sciences, AFOSR.....21

OAR RESEARCH REVIEW is published monthly by the Office of Scientific and Technical Information (RRYC), Hq Office of Aerospace Research, USAF, 4th and Independence Avenue, S.W., Washington, D. C. 20333. The objective of this publication is to make a positive contribution to the exchange of information concerning Air Force conducted and sponsored research activities. Individuals or organizations interested in or associated with research may obtain copies without charge by written request to the above address.

From the Editor:

There are many people, we may be sure, outside the realm of scientific research, who look upon science as a world unto itself, completely divorced from the other areas of human thought and speculation. It would be difficult for them to visualize, for example, any relationship between science and the humanities or arts. And yet, as Talcott Parsons points out in discussing the institutionalization of scientific investigation in The Sociology of Science, (Ed's: Barber and Hirsch)" . . . the great tradition of humanistic learning shares many features with science, above all the respect for impartial objectivity and hence for evidence . . . The humanistic scholar in this sense was in many respects the precursor of the scientist. . ."

Max Weber, writing on science as a vocation (also in The Sociology of Science), describes how Plato, in The Republic, consciously discovered the concept, ". . .one of the great tools of all scientific knowledge." He tells also how, in later years, during the Renaissance, the second great tool of scientific work, the rational experiment, made its appearance. "Without it," Weber adds, "present-day empirical science would be impossible." He describes how the great innovators of art, like Leonardo da Vinci, and the 16th-Century experimenters in music with their experimental pianos, were the pioneers of experiment and raised it to a principle of research. "From these circles," he points out, "the experiment entered science, especially through Galileo, and it entered theory, through Bacon. . ."

Da Vinci, indeed, had an appreciation of the intimate relation between man and nature which was anticipated more than a dozen centuries before by the Roman philosopher-emperor, Marcus Aurelius Antoninus, when he wrote, "Constantly regard the universe as one living being, having one substance and one soul. . ."

This concept of the unity of the universe is accepted by the scientists of today and is akin to the harmony of the universe visualized by the poet. It reminds one of the moving words by Walt Whitman when, in his poem, "When I Heard the Learn'd Astronomer," he tells how, "tired and sick" of the lecturing astronomer in the lecture-room, he slipped out into the ". . .mystical night-air, and from time to time, look'd up in perfect silence at the stars."

JACOB SEIDEN
Editor

Auger Transitions (Continued from P.1)

quantum is emitted. In the latter, one electron fills the vacancy while a second is simultaneously ejected from the atom carrying the excess energy. There is no light quantum or photon emitted in this case. The process is known as an Auger process after Pierre Auger who discovered these electrons in 1925. In the case of the lighter atoms, such processes are much more probable than are the radiative ones, and energy is transferred much more quickly through these radiationless transitions. Thus a knowledge of their transition rates is important to the study of energy transfer.

Unfortunately, the calculations are somewhat complicated by the nature of the transition, which is one between two electrons, with one going into a continuum rather than a discrete final state, as compared with the one-electron transition for the radiative case. The continuum wave functions are more difficult to handle mathematically, when they are not approximated by plane waves. Only through the use of large computers could the calculations be performed for more than perhaps a single atom in any reasonable period of time. A program was developed to do this for a variety of atoms ranging from light to heavy for what are known as KLL Auger transitions. These have an L-shell electron dropping into the initial K-shell vacancy, with another L-shell electron being emitted from the atom. The type of interaction responsible for the transition is the electrostatic interaction between the two electrons, and the transition rates are obtained from groupings of matrix elements of the type $(a\ b|1/r^2|c\ d)$ where a, b, c, and d are the appropriate initial and final wave functions of the two electrons. Even with the large computers available, it was necessary to approximate the wave functions by analytic

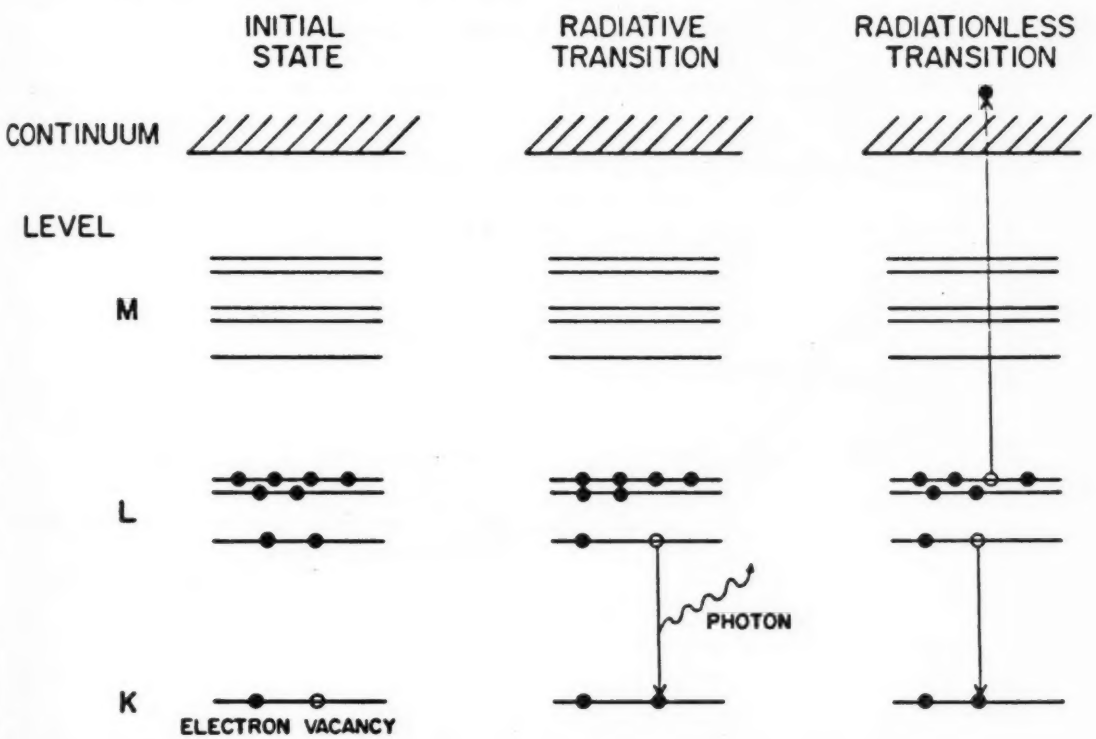


FIG. 1 TYPICAL COMPARISON OF RADIATIVE AND RADIATIONLESS TRANSITIONS

forms of screened hydrogenic functions since numerical functions are not yet available for many of the heavier atoms. The results of this work (2), together with the addition of spin-orbit terms when put into intermediate coupling (3), gave reasonable agreement with experimental intensities, except for the lighter atoms, where the question is still unresolved (Fig 2).

In this work it was necessary to develop new techniques for handling the hypergeometric functions involved; these are of general use in a variety of problems involving Coulomb interactions. The methods in this connection are based on matrix evaluation of the functions (4), and can be extended to other similar cases. The resonances in the two-electron continuum integrals as functions of energy were shown, using pure hydrogenic wave functions, which also provide an order-of-magnitude basis for understanding the energy-dependence of these transitions.

A logical extension of this work was to the Coster-Kronig transitions. These are Auger transitions where the initial vacancy is filled by another electron from the same shell. They also have the very interesting feature wherein they are only energetically possible for certain ranges of atomic number, and disappear otherwise. One particular transition, called the L_1L_2, 3 M_4, 5 transition, was chosen for detailed study because of its disappearance for atoms between antimony and tungsten, and its high transition rate as shown by the hydrogenic data. The results were found to agree reasonably well, qualitatively, with experimental spectral-intensity ratios (5). What was surprising was the remarkable sensitivity of the transition rates to changes in the electron wave functions and energy parameters (6). This sensitivity can be seen in Figure 3, with different screening representing different wave functions. The differences are capable of being distinguished experimentally, indicating which are the more appropriate calculated wave functions. At present, these measurements have not yet been made, since the level-width experiments needed are not simple to carry out.

The natural width of a level is the sum of the radiative and the Auger widths, or the

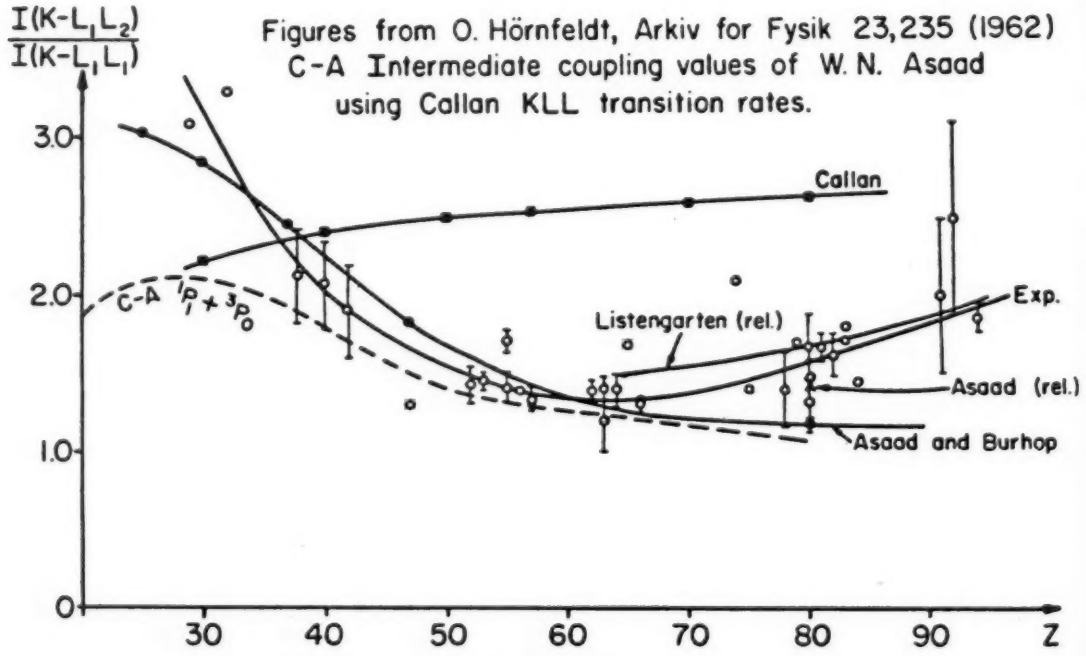


FIG. 2 THE RELATIVE INTENSITY OF THE K-L_1L_2 GROUP

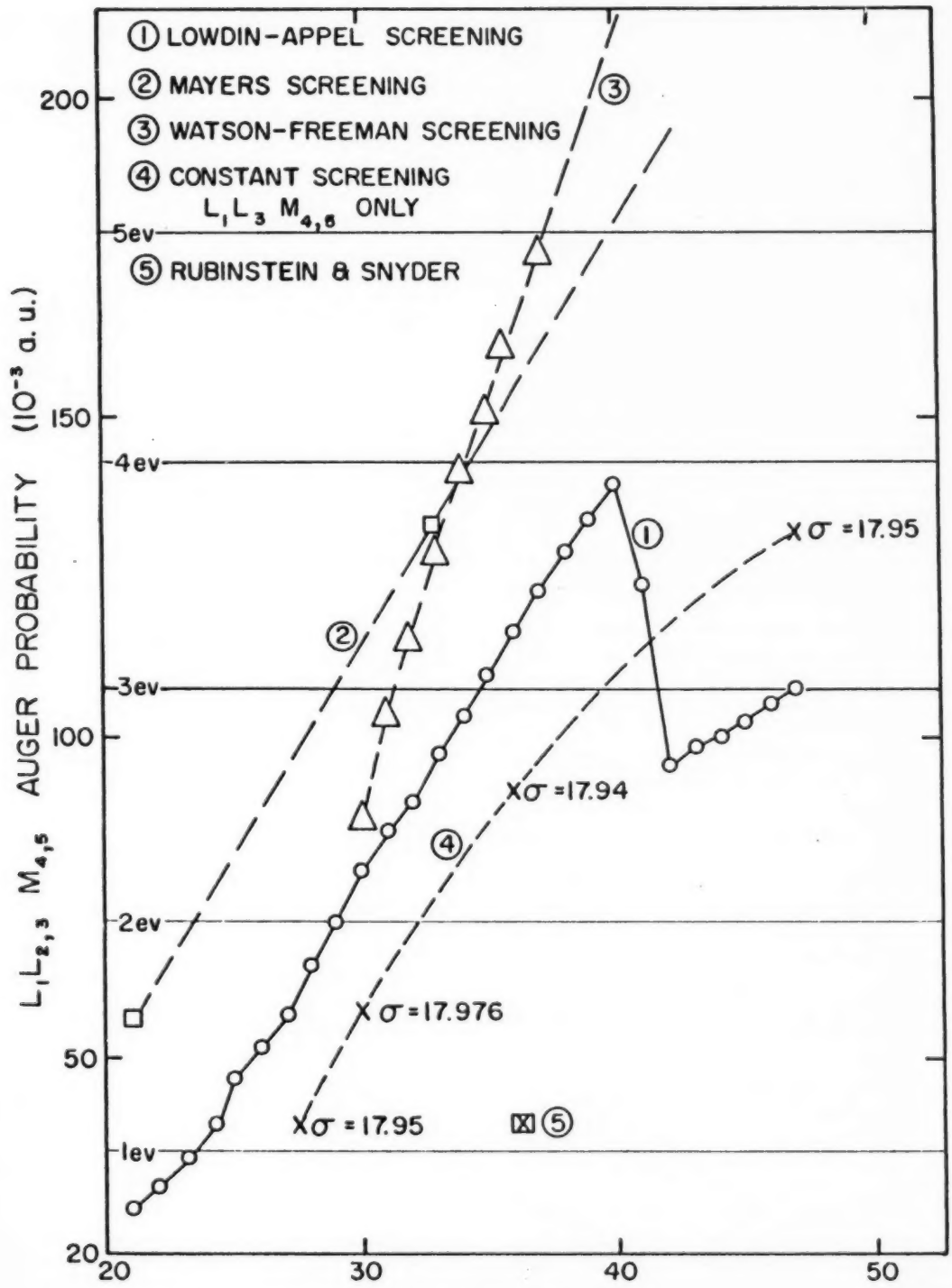


FIG. 3 ATOMIC NUMBER Z

sum of the transition rates. Only a few have been measured, even though this is a fundamental atomic property. It was noted that listings of K-level widths were given by Parratt of Cornell University, and Blokhin of USSR, which differed significantly. Using the calculated KLL widths, and systematic but empirical formulas for the radiative widths, the K-level widths were determined (7), the comparison in Fig 4 showing close agreement with the values of Parratt. Again, further experimental values are needed.

The results to date give reasonable values for a variety of Auger transition rates over a wide range of atoms, so that the trends can be seen. Through better wave functions, and through comparison with the experimental results yet to come, the discrepancies can be noted and explanations sought. Applications to various energy-transfer phenomena, and applications of the methods to molecular transitions, can be made. As usual, the partial filling of one of the lacunae leads to a clearer view of the many portions left unfilled, and the amount of leakage through the gap. The filling is for the future. ★

(1) Burhop, E. H. S., The Auger Effect and Other Radiationless Transitions, Cambridge Univ. Press, 1952.

(2) Callan, E. J., Phys Rev, 124, 793, 1961.

(3) Asaad, W. N., Nuclear Physics, 44, 399, 1963.

(4) Callan, E. J., P. Nikolai and W. L. McDavid, Proc Conf on Electronic and Atomic Scattering, London, 1963, North Holland Publ Co. (to be published)

(5) Callan, E. J., Proc Conf on Role of Atomic Electrons in Nuclear Transformations, Warsaw, 1963, (to be published).

(6) Callan, E. J., Revs Mod Phys, 35, 524, 1963.

(7) Callan, E. J., Proc . . . . Warsaw, 1963, op. cit., (to be published); Bull Am Phys Soc, 7, 416, 1962

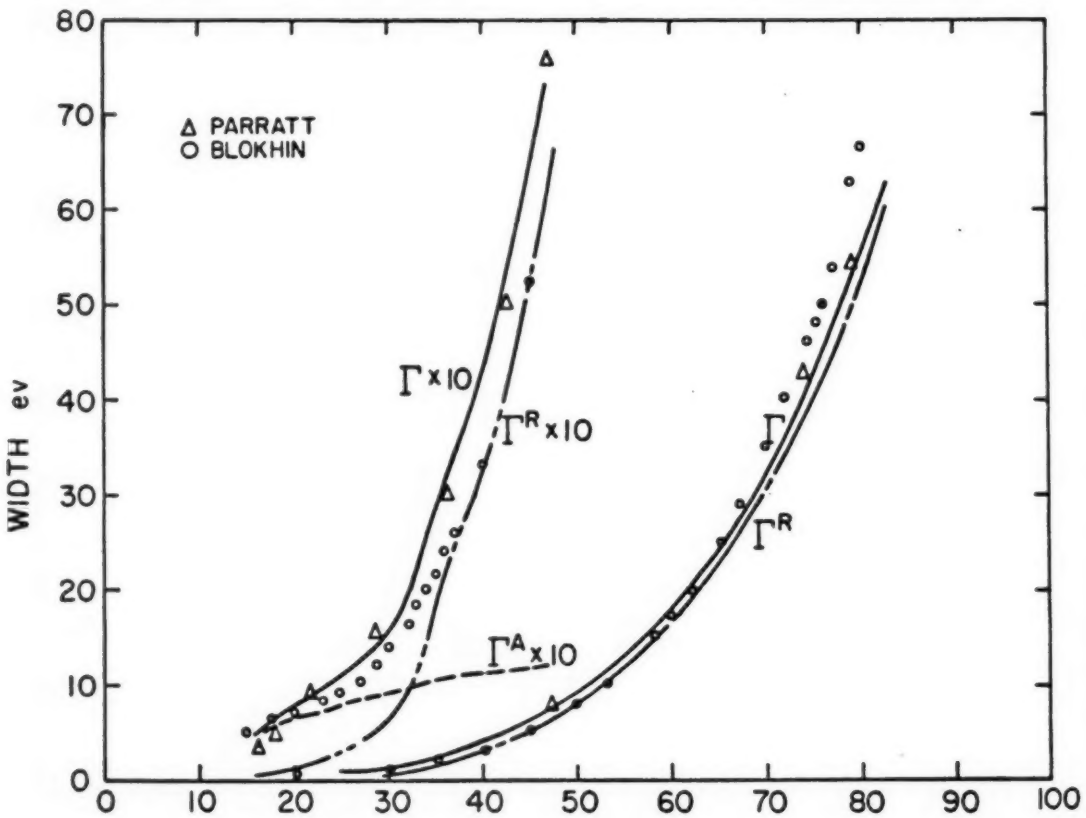


FIG. 4 ATOMIC NUMBER Z

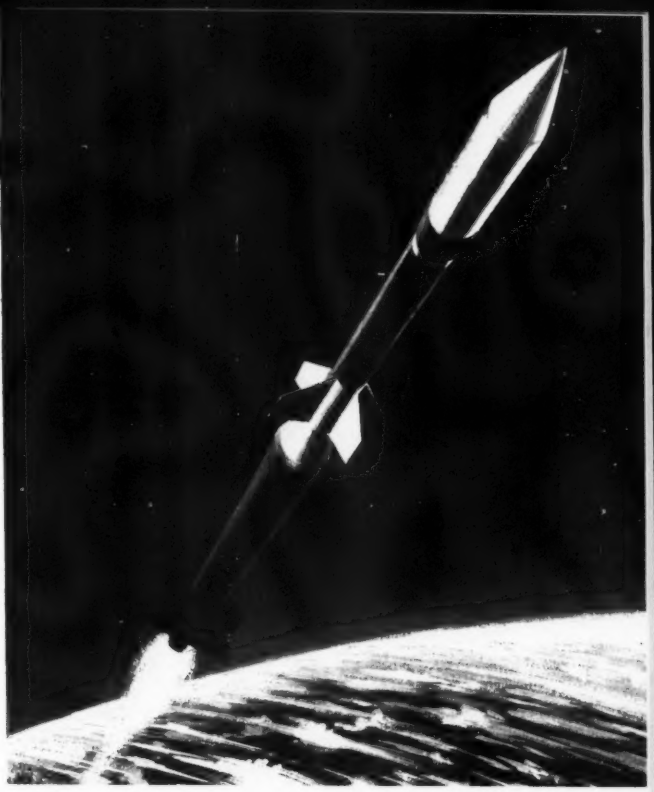
SOUND and TEMPE

DR. N. W. ROSENBERG
Upper Atmosphere Physics Laboratory, AFCRL

One of the first things we learn in high-school physics is that the velocity of sound varies with atmospheric temperature. This principle has been applied many times to atmospheric-temperature measurement. Such measurements--consisting of a detonation at altitude, and an acoustic detector on the ground--have, in fact, provided the most reliable estimates of ambient temperatures at altitudes up to 85 kilometers. But ground-based acoustic detection of detonations taking place at altitudes above 85 kilometers requires extremely large explosive charges. For example, more than 200 pounds of explosives are needed for ground-based acoustic detection of detonations at altitudes above 150 kilometers.

In a paper recently prepared by Dr. N. W. Rosenberg of AFCRL, an alternative technique for recording acoustic pulses of high-altitude detonations is discussed. This alternative technique was demonstrated in a rocket-borne experiment conducted by Dr. Rosenberg and his group in September 1963.

Although the technique involves the detection of acoustic pulses, optical--that is, photographic--means are used to record acoustic-wave propagation. The experiment used to demonstrate the technique was carried out at an altitude of 108 kilometers above Eglin AFB, Florida. The technique involved first the release of a glowing chemical trail by the rocket, and the detonation of an explosive charge from the same rocket in or near the trail. The gas was released from the forward section of the rocket, and the explosive charge (approximately 14 pounds) was released from the rear section. The detonation imposed a visible pressure pulse on the chemical trail. The gas used for the chemical trail was a mixture of triethyl aluminum and trimethyl aluminum. The gas glowed for a minute or so following release with an intensity sufficient to permit photography with a fractional-second exposure.



Two types of photographic records were obtained--a framed movie sequence, and a streak photograph. The streak-photographic record proved to be more valuable. Interpretation of the lines of enhanced luminosity on the chemical trail (representing the shock waves) is an involved mathematical process. The rapid expansion of the gas cloud, ratio of specific heats, molecular weights, and so on must be calculated. At an altitude of 108 kilometers, an acoustic velocity of 0.35 kilometers per second corresponds to a temperature of 300 degrees K, plus or minus 50 degrees. This figure, which was indicated on the basis of the photographic record of the experiment, compares to the value of 250 degrees K given in the U.S. Standard Atmosphere. (The U. S. Standard Atmosphere is a volume containing commonly agreed-upon values for atmospheric temperatures at various altitudes.)

AFCRL plans to investigate the technique further in additional programs to be conducted later this year. By means of multiple detonations at 10-kilometer intervals between 90 and 140 kilometers, temperatures over a range of altitudes can be measured during a single rocket flight. ★

the influence of hysteresis on skin effect

JOHN C. CORBIN, JR.
Plans and Analysis Office, ARL

An alternating current through a metallic wire is not uniformly distributed over the cross section of the wire, but is displaced more and more to the wire surface as the frequency of alternation increases. For very high frequencies, practically the entire current is concentrated in a thin layer at the wire surface while the current at the wire axis is nearly zero. This phenomenon is known as "skin effect."

For a wire of circular cross section, the distribution of current I, electric-field intensity E, and magnetic-field intensity H is shown in Figure 1. If the wire is a nonferrous conductor such as copper, a linear relation exists between the resulting magnetic-flux density, B and magnetic-field intensity, H; i.e., $B = \mu H$ where μ is a constant. For this linear relation between B and H, it is possible to obtain the distribution of current, electric-field intensity, and magnetic-field intensity as a function of radius in terms of Bessel functions. (1) The ratios of a-c resistance and reactance to d-c resistance can also be expressed in terms of Bessel functions.

On the other hand, if the current-carrying wire is a ferrous conductor, the linear relation between B and H no longer exists because of hysteresis effects. For weak magnetic fields, the resulting hysteresis loop can be represented by a parabolic relation between B and H. (2) The hysteresis loop is approximated by two parabolic arcs which form a small lancet. If B and H vary sinusoidally with time, a good approximation to the lancet form of the hysteresis loop is an ellipse, the equation for which is in parametric form. A comparison of the lancet form of the hysteresis loop and its elliptical approximation is shown in Figure 2.

Because of the nonlinear relationship between B and H, it is no longer possible to solve the skin-effect equations in terms of Bessel functions. Numerical methods must be employed to solve the equations.

Numerical methods have been developed at ARL by Pohlhausen and Corbin, and solutions were obtained for annealed iron wire with maximum magnetic-field intensities of 0.1 to 0.5 amp/cm. (3) Ratios of a-c resistance and reactance to d-c resistance were obtained and are compared in Figure 3 for an annealed iron wire with hysteresis and with no hysteresis (Bessel solution).

The method of solution is applicable to other ferrous materials. A paper by Schenk and Young (4) clearly shows that the parabolic relation and its elliptical approximation can be applied to silicon-steel specimens at low inductions. ★

REFERENCES:

1. *McLachlan, N. W., Bessel Functions for Engineers, Clarendon Press, 1955.*

2. *Rayleigh, Lord, "Notes on Electricity and Magnetism. On the Behavior of Iron and Steel under the Operation of Feeble Magnetic Forces," Phil. Mag., 23, No. 142, March 1887, pp. 238-241.*

3. *Corbin, J. C., "Influence of Hysteresis on Skin Effect in Ferrous Wires and Sheets for Weak Magnetic Fields," submitted in partial fulfillment of the requirements for the Master of Science degree, Ohio State University, 1963.*

4. *Schenk, H. L. and F. J. Young, "The Relationship of the Measured A-C Permeability at Low Inductions to the Dynamic Hysteresis-Loop Geometry," IEEE Transactions, Paper 63-107, 1963.*

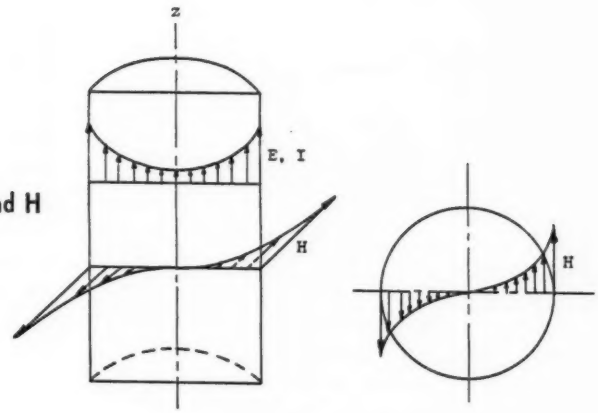


Figure 1 - Distribution of E, I and H for a Circular Wire

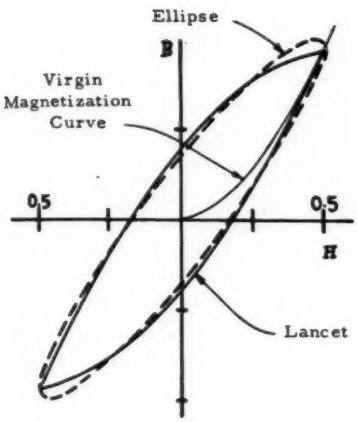


Figure 2 - Comparison of Lancet Form of the Hysteresis Loop and an Ellipse for H_m=0.5 amp/cm

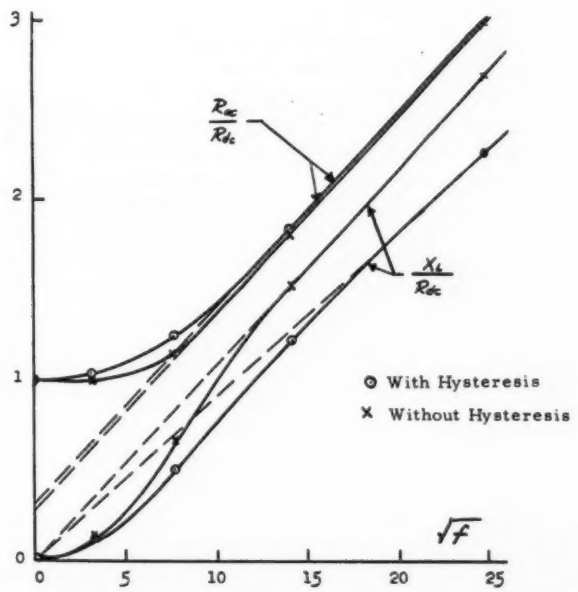


Figure 3 - Variation with Frequency of the Ratios of A-C Resistance and Reactance to D-C Resistance for H_m=0.5 amp/cm

THE IMPORTANCE OF A QUIESCENT PLASMA FOR PLASMA PHYSICS

WALTER FRIZ
Plasma Physics Research Laboratory, ARL

Plasma physics is concerned with phenomena occurring in a statistical assembly of charged and neutral particles, the movement of which is determined by external energies and internal mutual-partner interaction. Since many billions of these particles are contained even in a small volume, it is impossible to trace the kinetic history of each individual particle; therefore, a macroscopic average describing the state of the system has to suffice. This description of the state of such an assembly and its evolution in time is the aim of the theory of modern statistical mechanics.

Since, in physics, the agreement with reality serves as the ultimate judgment for the validity of theory, physical experiments must be undertaken for this purpose. These experiments, however, can only be considered conclusive if they are suitably designed. More precisely, such experiments have to reflect the assumed theoretical situation without adding unaccountable features above a tolerable error level.

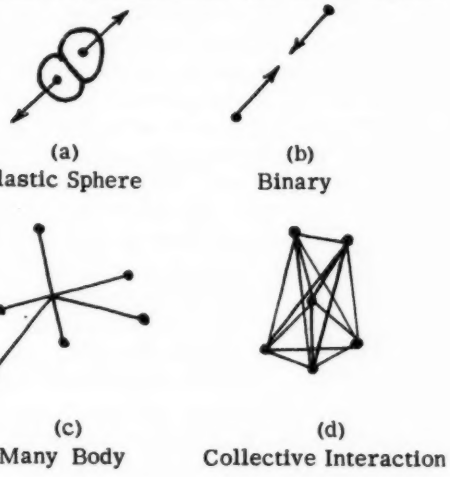
From the point of logical procedure, experiments in the physical sciences may be classified as two basic types: analytic (deductive) experiments and synthetic (inductive) experiments. In analytic experiments, the experimenter observes some phenomenon occurring in his apparatus and tries to deduce what particular causes may have led to it. In synthetic experiments, the experimenter decides by theoretical considerations that a certain arrangement under such and such conditions should produce the expected result, and plans his experiment accordingly. Because of the nonideal nature inherent in actual experiments, because of idealized assumptions in theory, and because of the temperament and habits of the investigator, in practical cases such a division is never clearly distinguished. This apparently unfortunate situation has its merits insofar as a few great discoveries have been made--not in spite of but just because of-- the nonideal apparatus and personal peculiarities of the investigator.

Experimental research in plasma physics uses laboratory plasmas as the medium in which various tests are performed. These plasmas may be classified somewhat artificially by the location of their creation: (1) plasmas generated by ionization within the experimental volume (local ionization); and (2) plasmas generated by ionization outside the experimental volume (distant ionization). In group (1) belong electrical discharges maintained by DC or RF fields via collision, radiation ionization, and fast-particle ionization. With few exceptions, these plasmas strongly reflect the mechanisms of ionization by exhibiting a strong carrier drift velocity, vorticity, etc.-- conditions which may spoil the plasma for synthetic experiment. Hot thermal equilibrium plasmas are not enumerated because their technical complexity puts them in an almost inaccessible realm for the experimenter. In group (2) belong "electron-tube" ionization, afterglow of discharges, diffusion halo of discharges, and alkali-metal surface-ionization plasmas. These plasmas are much less affected since the external energies producing the ionization are acting at some distance from the experimental area. Any disturbance connected with ionization has greatly diminished in the region where the plasma is used as an experimental medium.

It can be concluded, therefore, that experiments of a synthetic type designed for studies of plasma as an assembly of charged particles (and not a study of ionization as such) will utilize plasmas of group (2) above. Since the plasma will be close to thermal equilibrium and free from external fields (these are conditions not found in group [1] dis-

charges), the system conditions are fixed and allow for a relatively simple analytical description. Such a plasma is called a quiescent plasma.

In order to appreciate the merits of such a plasma in relation to present-day plasma physics, a brief discussion of the theory of particle dynamics is in order. Statistical assemblies of interacting particles may be classified according to particle interactions. Pictorial representations are shown below.



(a) Elastic Sphere

(b) Binary

(c) Many Body

(d) Collective Interaction

All types of interaction depicted here are possible in a plasma. Type (a) is an elastic-sphere interaction (e.g., ideal gas); type (b) is a binary interaction (e.g., idealized thin plasma); type (c) is a many-body interaction (e.g., simplified real gases and plasmas); and type (d) is a collective interaction (e.g., the general case of gases, plasmas, fluids and solids).

Elastic-sphere interaction (the simplest case) is an almost completed chapter of kinetic theory. Its macroscopic manifestations are known as dynamics of ideal gases, the concepts of which are used in many instances for an intuitive judgment of problems where a better theory does not yet exist.

Plasmas depending on average particle energy and density belong to types (b), (c), or (d). These interactions result in much more complicated theories. Important strides have been made in achieving more comprehensive theories which include liquids, crystals, and semiconductors as well as plasmas. New avenues of approach will follow quantum-mechanical methods and representations.

Judiciously designed synthetic experiments will contribute to the enhancement and furtherance of a theory of dynamics of interacting particles. Experimental confirmation of simplifying assumptions which make the analytical treatment possible is therefore an important contribution which experiments with a quiescent plasma can make. Close verification of boundary and initial conditions which are used by the theorist are possible using a quiescent plasma. ★

Ultrasensitive Magnetometer

DR. ERNST R. CZERLINSKY
Solid State Sciences Laboratory, AFCRL

AFCRL scientists have designed and constructed the most sensitive magnetometer yet developed for the measurement of magnetic properties of materials. The AFCRL instrument is about 100 times more sensitive than any other known magnetometer. Behind the development of this new and versatile instrument was the need to measure the magnetic properties of very small samples of materials.

When the sample is too small, magnetometers in general use are simply not sensitive enough to detect magnetic properties. Single crystals of certain materials, however, can be obtained only in very small size. The AFCRL magnetometer is an especially important development from the standpoint of compact electronic componentry packaging. As these packages become smaller and smaller, the need to measure magnetic properties of small samples of material becomes increasingly important. The AFCRL instrument can measure magnetic moments as low as 2×10^{-6} emu over the temperature range between 4.2 and 77 degrees K. At higher temperatures, where increased thermal noise limits sensitivity, the instru-

ment can measure magnetic moments as low as 2×10^{-5} emu.

The AFCRL magnetometer is a modification of the vibration sample magnetometer. In magnetometers of this kind, the sample is moved (vibrated) relative to a coil. Magnetic moments of the sample are measured on the basis of voltages induced in the coil. Sensitivities of vibration sample magnetometers are limited by such factors as vibration, thermal noise, 60-cycle pickup, and amplitude and frequency variations.

In the AFCRL instrument, sensitivities are limited almost solely by thermal noise. Other limitations have been greatly minimized through the design of the mechanism for vibrating the sample, and through the design of associated circuitry. In the AFCRL instrument, the signal coils are stationary, with their axis perpendicular to the magnetic field. The sample vibrates parallel to the magnetic-field axis. Vibration is accomplished by the same mechanism used to move the cone of a radio loud-speaker. The "speaker" vibrates at an optimum frequency of 82.5 cps, and has a maximum excursion of 2.5 mm. Actually, two synchronous speakers, placed back-to-back some distance apart, are used. When the two speakers are placed opposite one another, vibrational effects are greatly reduced.

For minimizing amplitude and frequency variations and extraneous noise, novel circuitry and shielding have been developed. The most critical component in the electronic system is a tuned amplifier in the signal circuit. This determines the band-width of the signal entering the mixing circuit, and hence determines the amount of noise introduced into the detection part of the system.

The magnetometer is capable of measuring samples at temperatures ranging from 4.2 to 600 degrees K. Temperature-control systems have been developed to permit measurements across this broad temperature range. This includes a special Dewar system for temperatures below 77 degrees K. To reach temperatures greater than 300 degrees K, a preheated gas is passed around the sample. ★

AFCRL *notes*

AFCRL has announced the purchase of 20 Aerobee-150 research rockets from the Space-General Corporation for use in a diversity of high-altitude research programs. Cost of the 20 rockets is $565,000. Deliveries will be made to White Sands Missile Range, N.M., periodically through September 1964. The Aerobee-150 rocket is 30 feet long and 15 inches in diameter. It can carry a 150-pound pay load to an altitude of more than 150 miles. (Aerospace Instrumentation Laboratory, AFCRL)

Simultaneous infrared spectroscopic studies of the lunar surface from the ground and from a balloon-borne telescope, carried out by AFCRL in late January, were only partially successful due to the failure of the balloon. For the ground-based portion of the studies, two AFCRL scientists used the Lowell Observatory's 42-inch telescope at Flagstaff, Arizona. From the study of the lunar infrared-emission spectra in the 17-25 micron range, good data were obtained which may provide improved understanding of the composition of lunar-surface materials. The balloon portion of the experiment was intended to provide complementary data across a broader infrared-spectral region than is possible with ground-based equipment. The balloon gondola, carrying a 12-inch telescope, was recovered by parachute after the rupture of the balloon, and was reflown on 27 February. Ground observations were made again at Flagstaff at that time. (Space Physics Laboratory, AFCRL)

An Aerobee sounding rocket was launched by AFCRL from the Fort Churchill Range on 4 February 1964. The 218 pounds of instrument were lofted to an altitude of about 128 miles to investigate auroral, electron and ion density. As the rocket ascended, the nose tip and a side panel were ejected to expose the sensing antennas. The basic scientific information was then telemetered to ground-receiving stations. (Upper Atmosphere Physics Laboratory, AFCRL) ★

SEMANTIC SPECTRA

ROWENA SWANSON
Directorate of Information Sciences, AFOSR

UNITED STATES TROOPS ARRIVE IN BERLIN AFTER BEING HELD UP ON THE AUTOBAHN

So read a recent newspaper headline. Were the troops accosted and robbed? Or were they detained? Or were they raised bodily or supported in some way?

These are a few interpretations or meanings which could be given to the headline. How does one specify the factual meaning? How would the sentence appear in translation, in another language? These are some of the questions faced by linguists who are trying to formulate rules for machine manipulation of natural language.

The consensus among designers and users of information systems is that the systems must eventually include machines capable of processing natural language. It should be unnecessary for commanders to learn the rules of an artificial, so-called "machine language" before they can give orders or receive information. Under stress, trained personnel might forget or garble a rule. At present, there is a plethora of machine languages. The incongruous situation could be imagined of persons trained in one language and assigned to a machine responsive to another.

In practice, great strides have been made in the design of simplified machine languages. Languages exist in which scientific, military, and business problems can be phrased by persons not skilled in the machine programmer's art.[1] "Compilers," i.e., translation programs, are being developed by which machines can convert one machine language into another. These languages are powerful, useful tools which minimize the time between man's need-to-know and the accessibility to him of the information store in the bowels of a machine.

Other strides have been made in the analysis of the structure of natural language, i.e., syntactics, and in the analysis of the frequency of occurrence of words in natural language.[2] Limited sentence structures can be parsed, or subdivided, into functional units, e.g., noun phrases and prepositional phrases. Such subdivisions are indicators of meaning. From word-frequency data, meaningful indexes to content can be automatically generated. Words can be mechanically matched with other words in look-up dictionaries for both machine construction of indexes and for machine translation from one natural language to another.

Problems of semantics and related pragmatics, i.e., the meaning of natural-language text which the user of the words intended to convey, are largely unsolved. These problems may be part of the broader set of problems concerning how man recognizes and processes patterns, and how he stores, manipulates, and retrieves information. However, the large data-mass-manipulation capability of computers is being harnessed by one AFOSR contractor to explore another avenue to the solution of semantic problems.

Under AF 49(638)-1128, Dr. Paul L. Garvin of Thompson-Ramo-Wooldridge, Inc., has been investigating an approach he calls predication typing. The research procedure consists in the assignment, by a native speaker, of a replacement sentence for a given sentence. These replacement sentences are chosen from a limited set called predication types. Each predication type represents a semantic feature of the original form. For example, a statement of succession has the replacement form "A is followed by B;" an assertion of adequacy is replaced by "A satisfies the conditions for B;" a description of performance is replaced by "A is accomplished by means of B." Thirty-three predication types have been found adequate thus far from an analysis of approximately 4500 sentences.

This approach permits the analysis of two semantic dimensions. First, original forms reducible to a given replacement form can be examined. This grouping shows degrees of

synonymity within natural language. Second, the set of replacement forms for a given original form indicates a semantic spectrum for the original form. For example, a partial spectrum of the form "come; comes" is as follows:

a. the value for fluorine comes from Naddocks' paper; the value for fluorine is based on Naddocks' paper
b. particles come to earth
particles arrive at earth
c. the atomic weight of oxygen comes to 16 times that of hydrogen; the atomic weight of oxygen has the value of 16 times that of hydrogen
d. the calculations come within the limits of observational error; the calculations satisfy the conditions for observational error

The semantic spectrum gives a rough indication of the range of meaning of the form.

Determination of the relative frequencies of occurrence of the replacement forms in spectra is planned to establish weights assignable within the spectra. The goal is to establish a measure of synonymity which can precisely represent this aspect of semantic structure.

An unexpected finding in the research has been that original forms for which replacement forms were chosen were not limited to predicative words and phrases. Original forms include words of all classes, including conjunctions and prepositions. All replacement forms are predicative. Thus, the statement, "Once freezing is initiated, the drops grow ...,"rephrased on the non-predicative element, "once," becomes "Initiation of freezing is followed by growth of drops...." Hence, semantic classification does not coincide with formal grammatical division into word classes. Function words, e.g., conjunctions and prepositions, viewed by predication typing, are significant bearers of meaning. Dr. Garvin's application of an empirical method to the processing of semantic data may yield a system of meanings comparable to the system of forms capable of ultimate manipulation by machine.[3] ★

REFERENCES:

1. *Sherman, P. M. and B. A. Stevens, "Bibliography 8. Digital Computer Programming, 1955-1961," Computing Reviews, vol. 4, no. 4, 191-202, July-August 1963.*

2. *"Current Research and Development in Scientific Documentation, No. 11," NSF-63-5, Nov. 62, section 5.3 on Linguistic and Lexicographic Research.*

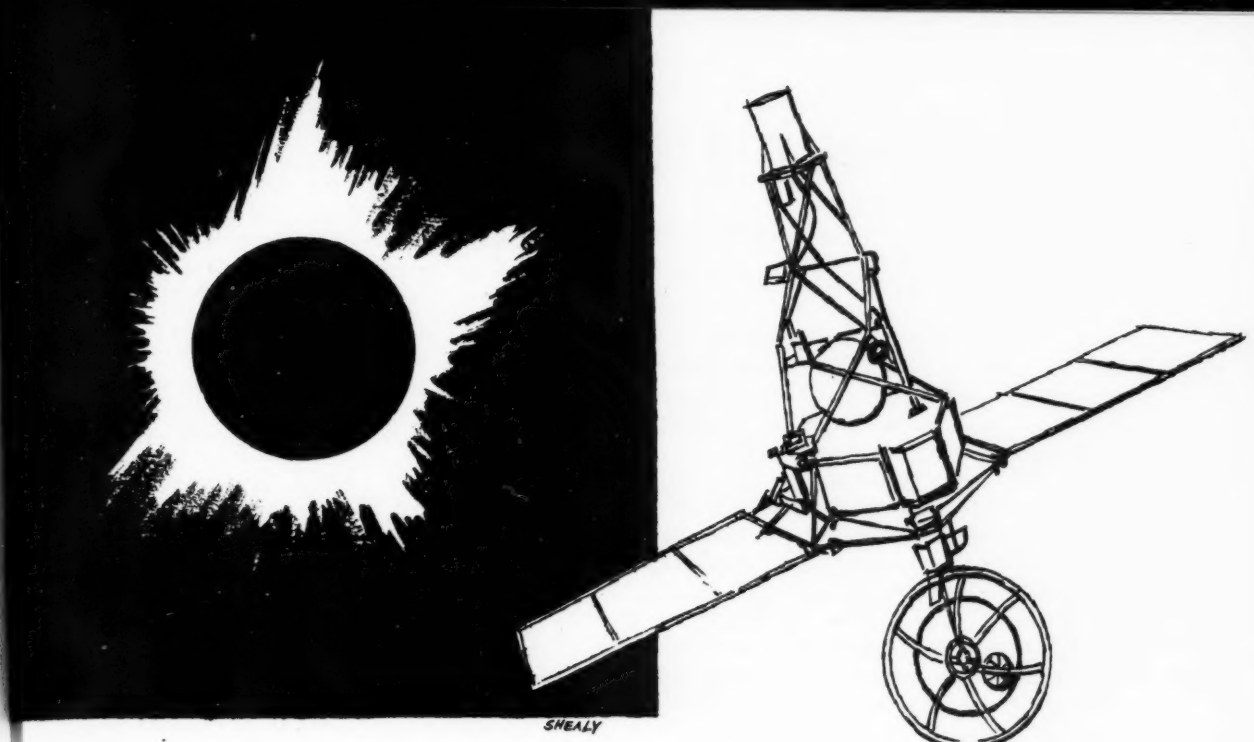
3. *Garvin, Paul L., "Research in Semantic Structure," Technical Note No. 6 under AF 49(638)-1128. Paper Presented at the 37th Annual Meeting of the Linguistic Society of America, New York, 28-30 Dec. 62.*

evaporation of the SOLAR CORONA

DR. HARI K. SEN, Space Physics Laboratory, AFCRL

The earth moves through a constant, steady wind which always flows outward from the sun through interplanetary space. These winds have been measured by various space probes--Lunik II, Explorer X and Mariner II. They are composed of free electrons and protons. But their origin and the physical processes which give rise to these solar winds have not been fully understood.

In a theoretical study, Dr. Hari K. Sen of AFCRL has shown that solar winds originate through the evaporation of the solar corona. Electrons and protons boil off from the corona in much the same fashion that a liquid evaporates when it reaches a certain critical temperature. (The solar corona has a temperature of about a million degrees K compared with only about 6,000 degrees K on the visible disk of the sun.) Dr. Sen has evolved a simple physical (kinetic) theory explaining just how the electrons and protons of the solar winds escape from the corona. He has then compared his results with the observed interplanetary electron densities and with the experimental data obtained from space probes on the densities and velocities of solar winds in the vicinity of the earth. The theory agrees in order of magnitude with the experimental data, and gives an estimate



of the interplanetary electron density beyond the observed range from the sun. Dr. Sen's theory of coronal evaporation shows that the solar corona makes an appreciable contribution to interplanetary-plasma density and to the observed flux and energy of the solar wind near the earth.

For his mathematical model, he has incorporated the formulations of others working in related fields, one of these being Jeans' formula for the escape of gases from planetary atmospheres. The computation of particle-density and energy values of the solar wind requires the consideration of many factors--the solar-magnetic and gravitational fields, electrical fields, the mean free path of particles, and so on.

Dr. Sen sets the critical altitude for the escape of protons and electrons into interplanetary space at about four solar radii, or at about 1,300,000 miles above the visible solar disk. His calculations consider only protons; it is, of course, unnecessary to consider both electrons and protons since the loss rate is roughly the same for both of them. He makes other simplifying assumptions: that the corona is spherically symmetrical, that electrons and protons flow out from the corona at a steady rate from all regions of it, and that the coronal magnetic field and rotation have no effect on the flow.

The formulations show that the loss of solar mass by coronal evaporation (of the order of a million tons per second) is comparable to solar-mass losses by radiation. The coronal material lost by evaporation is replenished by material flowing from lower regions into the corona. The evaporation process, Dr. Sen notes, tends to serve as a coronal thermostat. The rate of evaporation increases with temperature; this, in turn, serves to lower coronal temperatures.

The theory gives rise to speculation on the possibility of similar winds being generated by giant stars. The coronas of these giant stars are likely to be extensive and result in stellar winds of great intensity. The resultant high loss of mass may affect the evolution of these stars. Dr. Sen's formulation suggests that these giant stars may also contribute to galactic X-radiation. ★

research needs in MFD

KENNETH R. CRAMER
Thermomechanics Research Laboratory, ARL

The study of flow problems of electrically conducting fluids, particularly of ionized gases, is currently receiving considerable interest. Engineers and applied physicists began their investigations around 1950 when the importance of controlled fusion research and space technology became evident.

A recent report* prepared for the Aerospace Research Laboratories by Dr. Shih I. Pai of the University of Maryland presents a critical survey of magnetofluid dynamics with special emphasis on its fundamental features and the new phenomena which differ from those of ordinary fluid dynamics. After a preliminary discussion of the fundamental equations of magnetofluid dynamics and their properties, several typical flow problems are analyzed which include one-dimensional flow, MFD-power generation, inviscid and viscous flows.

A significant feature of Dr. Pai's report is his observations and recommendations. The more important ones are quoted below:

"A major portion of research on magnetofluid dynamics is theoretical. However, because of the large variety of new solutions, true understanding of the problem is difficult. For instance, in general it is impossible to predict the influence of a magnetic field on the forces on a body in an electrically conducting fluid except in a few simple cases. In many regions of interest, one is even incapable of predicting the sign of the expected effect, e.g., whether the drag will increase or decrease if a field is applied or whether the heat-transfer rate will increase or decrease when a field is applied.

"For an ionized gas or a plasma, the basic equations of MFD are insufficient. Some improvements of these basic equations should be made. One way to improve the basic equations is with multifluid theory; however, it is very complicated and little has been done for such a complete treatment of the flow of a conducting fluid.

"For many engineering problems, we are interested mainly in the over-all effects, and thus it is advisable to study some simple-flow problems such as one-dimensional flow in a channel with all possible boundary conditions, together with experimental research.

"Theoretical investigation in MFD should be carried out in close cooperation with experimental research so that a full understanding of this complicated problem is possible. Experimental research will furnish important knowledge to this new science. First, it may verify or disprove the theoretical results, particularly the simplifications and assumptions used in the theory. Secondly, experimental results may improve our knowledge in the regimes where little theoretical results are available, and furnish data so that new theory may be formulated. At the present time, the correlation of the theoretical and experimental research in MFD has not been developed successfully such that a unified approach is possible.

"A considerable amount of experimental work in MFD has been performed. Most of the experimental investigations are still in a stage of developing the experimental technique, and they furnish little information for true understanding of flow problems in MFD. Good and interesting experimental research results are still few and are greatly needed to improve our knowledge in magnetofluid dynamics. However, there are many technical difficulties to be solved before critical experiments with the flow of conducting fluids can be carried out.

"One of the most promising experimental techniques is the investigation of the flow of electrically conducting fluids such as mercury, sodium or salt solution whose properties are known and for which the MFD parameters can be varied over a large range so that their essential effects on the flow can be examined."

In conclusion, Dr. Pai comments that "since our knowledge of turbulent flow in ordinary fluid dynamics is still meager, we could expect little theoretical progress for turbulent flow in MFD. But experimental research for turbulent flow in MFD should be carried out."

*"*A Critical Survey of Magnetofluid Dynamics - Part I: General Discussion,*" by Shih I. Pai, University of Maryland, College Park, Maryland, ARL 63-175, Part 1, 1963.*

PYROLYSIS of FLUORINATED ORGANIC COMPOUNDS I.

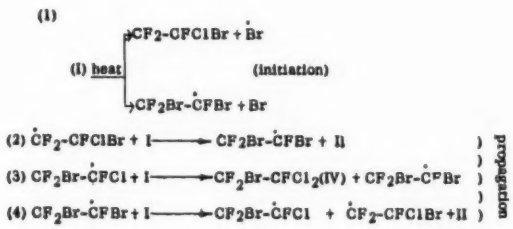
1, 2-DIBROMO-1-CHLORO-1,2,2-TRIFLUOROETHANE and SOME RELATED HALOGENATED ETHANE DERIVATIVES

J. D. PARK, CAPTAIN R. W. LAMB, and J. R. LACHER
The Frank J. Seiler Research Laboratory

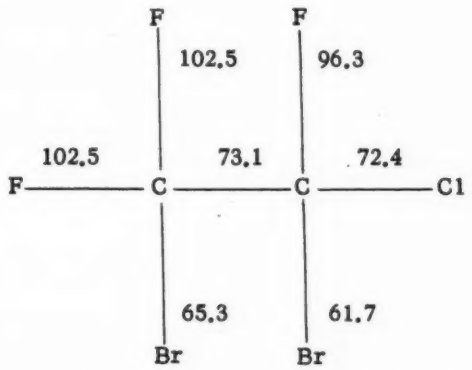
The synthesis of various halogenated ethane derivatives was performed by the pyrolysis of CF_2Br-CFClBr and other similar compounds. It is postulated that, at temperatures up to 600°C, the initiation step of the reaction involves mainly the homolytic rupture of carbon-bromine bonds. The products were isolated and used as evidence to postulate reaction paths involving intermediate free radicals.

The same general procedure was used for all of the pyrolysis reactions. The reactants were added from a burette or a gas cylinder into a pyrolysis tube enclosed in an electric furnace. The tube used for the pyrolysis was a platinum-lined inconel-jacketed nickel tube about 24 inches long and 3/4 inches in diameter. A section of the tube, about 12 inches long, was enclosed in the furnace. In order to have a distinct boundary for the region of pyrolysis, tap water was circulated through copper coils wrapped around the tube at the ends of the furnace. The volume of the section of tube used for pyrolysis was required in order to calculate the contact time. The temperature of the reaction was measured with a chromel-alumel thermocouple, which was inserted into the furnace along with the pyrolysis tube. The contact time was calculated by dividing the volume of the pyrolysis tube by the rate of flow of the reactants through the tube. The relative amounts of the products obtained was determined by gas chromatography.

It was shown that the pyrolysis of CF_2Br-CFClBr(I) produced two major products, CF_2Cl-CFClBr(II) and CF_2Br-$CFBr_2$(III) in addition to the starting material. The following reaction paths can be used to explain the products:


(1)
CF2-CFClBr + Br
(I) heat
(initiation)
CF2Br-CFBr + Br
(2) CF2-CFClBr + I → CF2Br-CFBr + II
(3) CF2Br-CFCl + I → CF2Br-CFCl2(IV) + CF2Br-CFBr
(4) CF2Br-CFBr + I → CF2Br-CFCl + CF2-CFClBr + II
propagation

The bond-dissociation energies (Kcal/-mole) were calculated for the starting material (I), according to the equation developed by Errede.[2]



Assuming that the ease of breaking a bond in the initiation step is a function of the bond-dissociation energy, it is postulated that the initiation step in the pyrolysis of (I) involves primarily the rupture of carbon-bromine bonds as shown in reaction (1).

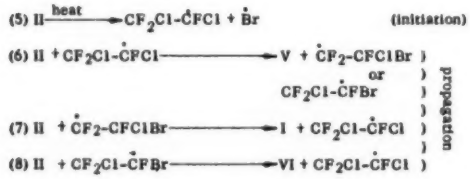
A small amount of CF_2Cl-$CFBr_2$(VI) was also shown to be present in the product which indicates the presence of the free radical, CF_2-$CFBr_2$ or CF_2Cl-CFBr, during the course of the reaction. Both of these free

radicals could originate from the further reaction of the products obtained in reactions (2) and (3).

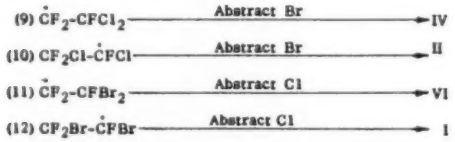
There was no (IV) isolated in the product; therefore, the rate of reaction (3) must be slow compared to (2) and (4).

When a mixture of (I) and bromine was pyrolyzed, the same products were obtained in the same proportions as were obtained when elemental bromine was not used in the reaction. However, the yield was drastically reduced when (I) was pyrolyzed in the presence of nitric oxide as would be expected for a reaction involving free radicals.

When (II) was pyrolyzed, $CF_2Cl\text{-}CFCl_2$(V), (I) and (II) were the only products isolated. These products can be accounted for using the following reactions.

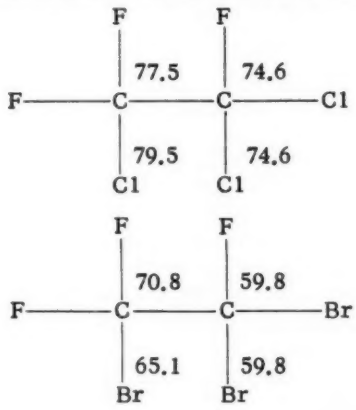

(5) II heat CF2Cl-ĊFCl + Ḃr (initiation)
(6) II + CF2Cl-ĊFCl V + ĊF2-CFClBr or CF2Cl-ĊFBr
(7) II + ĊF2-CFClBr I + CF2Cl-ĊFCl
(8) II + CF2Cl-ĊFBr VI + CF2Cl-ĊFCl
propagation

Pyrolysis of an equimolar mixture of (V) and (III) produced (I), (II), and (VI) as the major products. Four different free-radical intermediates are possible from the pyrolysis of (V) and (III). The combination of these intermediates with a bromine or chlorine atom should lead to the formation of the products as follows:



The products which were isolated furnish evidence for reactions (10), (11), and (12). Since IV cannot be isolated from the pyrolysis, it appears that either appreciable amounts of $\dot{C}F_2\text{-}CFCl_2$ are not present during the reaction, or reaction (9) is slow compared to (10), (11), and (12). It is presumed that the carbon-chlorine bond in the chlorodifluoromethyl moiety of (V) is not appreciably broken under the conditions of the reaction. This particular bond is known to be relatively strong because of the strong negative inductive effect of the two fluorine substituents.[3]

Using the equation developed by Errede,[2] a quantitative comparison of the strengths of the bonds in (V) and (III) can be made. The following model illustrates some calculated bond-dissociation energies in Kcal/mole.



It is presumed from the above calculated bond-dissociation energies that the initiation step involves primarily the breaking of carbon-bromine bonds in (III). Furthermore, the rate of production of $CF_2Br\text{-}\dot{C}FBr$ should exceed that of $\dot{C}F_2\text{-}CFBr_2$ because of the difference in the bond-dissociation energies of the carbon-bromine bonds in III. Production of free radicals from (V) probably occurs during the propagation steps by reaction of (V) with either $\dot{C}F_2\text{-}CFBr_2$ or $CF_2Br\text{-}\dot{C}FBr$.

BIBLIOGRAPHY

1. *Frank J. Seiler Research Laboratory, Office of Aerospace Research, United States Air Force Academy, Colorado. This paper represents part of a thesis submitted by R. W. Lamb to the Graduate School, University of Colorado, in partial fulfillment of the requirements for the Ph. D. degree, June 1961.*

2. *Errede, L. A., J. Phys. Chem., 64, 1031, 1960.*

3. *Steunenberg, R. K. and G. H. Cady, J. Amer. Chem. Soc., 74, 4165, 1952.*

4. *Haszeldine, R. N., J. Chem. Soc.,3423, 1952.*

5. *Presented by Captain R. W. Lamb at the 146th National Meeting of the American Chemical Society at Denver, Colorado, 19-24 January 1964.*

OAR PROFILES

Mr. Walter Friz, a research physicist with the Plasma Physics Research Laboratory, ARL, is currently carrying on research in particle kinetics in plasmas. Studies are being undertaken on the nature of collisions in a low-density plasma. These studies are motivated by discrepancies in the results of theoretical work on this subject. Studies also falling in the area of particle kinetics will be carried out in a cesium plasma. Mr. Friz has the degree of Diplom-Ingenieur from the Institute of Technology, Stuttgart, Germany (1951). He has worked with private industry, and has been at WPAFB since 1950. In this Review, he writes on "The Importance of a Quiescent Plasma for Plasma Physics."

Mr. Kenneth R. Cramer, a scientist with the Thermomechanics Research Laboratory, ARL, is currently conducting analytical investigations of various phenomena in flows of electrically conducting and nonconducting fluids. He is also doing analytical investigations of radiant-heat transfer. He has an M.S. degree from Ohio State University (1956) and a B.M.E. from the University of Dayton (1951). Mr. Cramer has also been a Registered Professional Engineer in Ohio yearly since 1954. His employment with ARL goes back to July 1951. In this current issue of the Review, he writes on "Research Needs in MFD."

Mr. John C. Corbin, Jr. is with the Plans and Analysis Office, ARL. He has a Bachelor of Electrical Engineering degree from Cornell University (1950) and an M.S. degree in Electrical Engineering from the Ohio State University Graduate Center, WPAFB, Ohio (1963). He served with the U.S. Navy from 1944 to 1946. Mr. Corbin has worked as a development and project engineer with private industry, and as an aeronautical research engineer at Wright-Patterson AFB. He is a Professional Engineer in the State of Ohio. He writes currently on "The Influence of Hysteresis on Skin Effect."

all-plasma RADAR SYSTEM

SHELDON B. HERSKOVITZ
Microwave Physics Laboratory, AFCRL

An all-plasma radar system is theoretically feasible. In this radar, all major operations can be performed by plasma devices. Some of these plasma devices have already been developed, some represent techniques presently available and awaiting application, and others are merely theoretically promising. Sheldon B. Herskovitz of AFCRL has taken all these available and promising techniques and has described a hypothetical radar system based on them. In a recently prepared paper, he has discussed some of the components of the system, reviewed their advantages and disadvantages, and has commented on the feasibility of the over-all system.

The system suggested by Herskovitz would incorporate plasma-power sources, plasma oscillators and amplifiers, plasma wave guides, plasma detectors, plasma antennas, and plasma-display devices. For these components, Herskovitz has drawn upon the results of plasma research at AFCRL and at laboratories all over the world. In his paper, he notes that several gaps in technology still exist before the all-plasma radar can become a reality, and these gaps offer challenging areas for fruitful research. Among the potential advantages of the system would be large band-width operation, high-power handling capability, and high tolerance to the effects of radiation.

The power source for the system may be one of several plasma-power sources presently being studied--thermonuclear, magnetohydrodynamic or thermionic. Power from the source is supplied to a plasma oscillator-amplifier to produce microwave pulses. Experimental work to date indicates that a suitable plasma oscillation-amplifier can be constructed.

Plasma techniques for oscillation multiplication are presently being studied by a number of workers and are particularly promising for the generation of millimeter or submillimeter waves. Energy of these wave lengths are useful because they make possible high resolution of closely situated targets.

The transfer of energy within the hypothetical all-plasma radar system can be accomplished through the use of plasma wave guides. Plasma columns or rods surrounded by a dielectric, or a dielectric-and-metal boundary, can propagate electromagnetic energy in various surface modes. Hollow plasma columns can act as circular wave guides, transmitting energy within the column. Such guides may have lower transmission losses than conventional guides. Also, the physical dimensions of the plasma guide can be controlled externally, thus providing a method for optimizing propagation characteristics over a wide spectrum of electromagnetic energy.

Plasma devices can also be used to measure the frequency, amplitude, and power of microwave signals, and for matching the various components of the system. For this purpose, plasma Faraday rotators, directional couplers, switches, attenuations, and phase shifters have been developed.

The realization of a complete plasma-radar system must await the development of a plasma antenna. Antenna research at AFCRL has included studies of the coupling of microwave energy to long plasma columns whose lengths can be varied electronically. The possibility of combining such plasma columns to achieve beam scanning and variable-frequency operation will be studied by AFCRL in the future.

AFCRL has also studied the applicability of the variation of light output from a decaying plasma as a sensitive detector for echo signals. Using a plasma column inserted into a squeezed wave-guide section, such a detector can respond to microwatt peak-power signals. It takes advantage of the dependence of radiative recombination on electron temperature. When the electrons of

a decaying discharge are irradiated by a microwave signal, they absorb energy with a resulting increase in electron temperature. This increased electron temperature can be monitored, thus serving as a detector of microwave energy.

A plasma detector offers several advantages. It is extremely broad-banded. Unlike a crystal detector, it can be exposed to megawatts of microwave power with no permanent damage, a feature which eliminates the need for protecting the detector while the transmitting section of the system is operating. Finally, because it does not function until a decaying plasma is established, the device may be readily gated into operation at selected times. ★

experiments in human communication

DR. HAROLD WOOSTER
Directorate of Information Sciences, AFOSR

Physicists, we are told, weep nostalgically in their beer for the good old days, when apparatus was built with Jena glass, string and sealing wax. Not so the psychologists, who can still find interesting things to do with simple apparatus.

One of these psychologists is F. L. Brissey of the University of Montana at Missoula. Brissey has been doing research on "Factors of Urgency, Mastery and Set in Serial Reproduction of Information," under AFOSR Grant 62-114, with a rig built out of Masonite pegboard (1/8" holes on 1" centers), wrapping paper, posterboard, and a couple of cups of golf tees for a total cost of, say, $10 for materials.

The test is diabolically simple. Two pieces of pegboard are hinged together with the holes in line to give a test area of 16 x 16 holes. Between them is sandwiched a piece of wrapping paper and a piece of posterboard with a pattern cut out of it. The subject is given a handful of golf tees and told to find out what the pattern is by sticking them in the holes in the top piece of Masonite. "Hits" go all the way through, "misses" stay on the top sheet. Subjects are scored on discrimination, which is the ratio of the total number of golf tees used to those in the target area, and completion, which is defined as the percentage of the display in which pegs were placed.

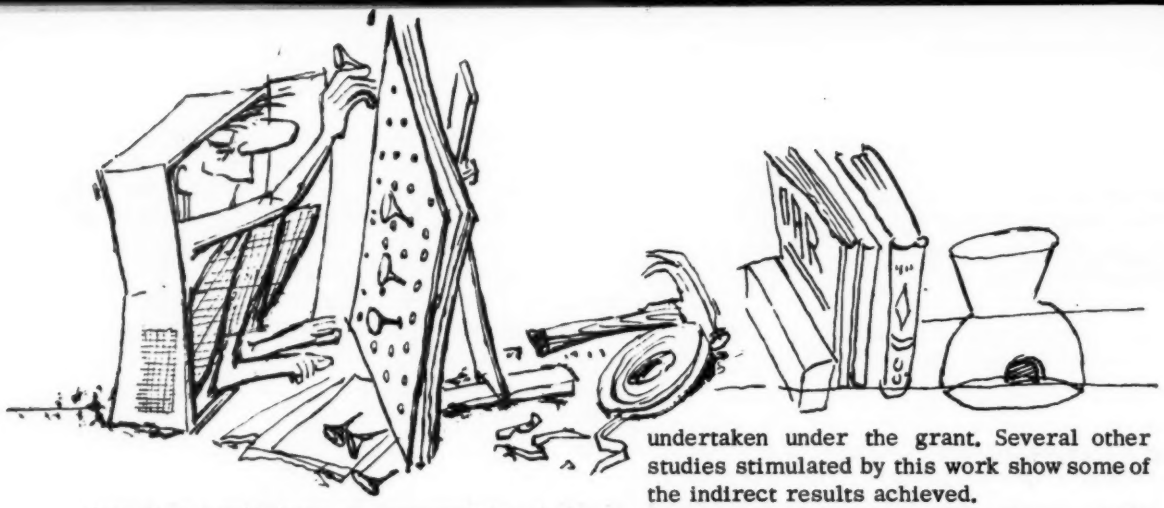
After the subject has finished, or thinks he has, he is asked to record a tape, which is then played back to a second subject who tries to follow the instructions of the first and rediscover the pattern.

The first series of experiments tested the effects of situational feedback--leaving the template in place when the receivers were trying to duplicate the pattern. Receivers with and without feedback did about as well, but were actually significantly less effective than a control group which had the template in place but got no instructions from the first subjects about the pattern.

It looked as if the instructions from the subjects were hurting, rather than helping performance, so the next step was to cut an ideal message tape using a professional radio announcer to read a carefully prepared text. After this, the differences disappeared. A bad message was worse than none at all; a good message did help performance.

The next condition investigated was the influence of communication set--to determine if it made a difference whether or not subjects were told before they tackled the test that they would have to tell someone else how to do it. Two transmitter groups were used; one was told only that it had a problem to solve--the other, that it would not only have to solve the problem itself, but also have to tell someone else how to solve the problem.

Not surprisingly, the subjects who were told



that they would have to communicate their solutions not only did a better job of communicating, but also did a better job of learning the displays.

The effects of transmission time were the next to be tested. One group of transmitters was told that it could take as long as it wanted to describe the solution; the other group was cut to one third of that time. The essential finding of the study was that cutting the time reduced the amount of display completed by the receivers, but without loss in discrimination, as long as they did not have to complete the display. When they had to complete the display, the receivers for the long-winded group worked at a significantly higher level of discrimination. In general, a reduction in the time available for transmission is not necessarily associated with a loss in communication effectiveness, if effectiveness is defined in terms of discrimination.

Another set of tests tried the effects of scrambling the message materials by randomizing sets of four sentences of the original messages, and by randomizing every sentence of the original message. As expected, the more the messages were scrambled, the worse the results. There was one surprising result, however--an apparent sex difference in favor of women. When the performance of subjects used in this study was analyzed by sex, the findings "tended to support the conclusion that the females functioned slightly better as receivers than did the males." As Brissey says, "The entire question of sex differences in the communication process is in need of research development."

The foregoing summarizes the formal work undertaken under the grant. Several other studies stimulated by this work show some of the indirect results achieved.

One is a study to investigate the use of the apparatus and procedures for the study of communication among those profoundly handicapped in their hearing, using the manual-sign language for transmitting information. A similar study has been started to investigate the transmission of information by the sole use of gestures and facial expressions.

There is a suggestion that the ability to solve the "display problem" may be significantly correlated with intellectual ability as measured by standard college-entrance tests. The apparatus and procedures may have utility as a nonverbal (language-free?) approach to the measurement of intellectual capacity.

Finally, observations of both transmitter and receiver performance made throughout the course of this work indicate the distinct possibility of adapting these procedures for use as a communication-ability screening test. There are pronounced individual differences in both transmission and reception performance. A research program aimed at identifying factors associated with these differences and establishing empirical performance norms may yield useful information for a variety of agencies where interpersonal communication is important.

Incidentally, there is even more Air Force flavor to this research than appears from this summary. The principal investigator, Dr. Forest Lee Brissey, is a former Air Force colonel (Operations and Command, 1941-1945, combat operations, Southwest Pacific), and most of the test subjects are volunteers from the local Air-ROTC group at the University of Montana. ★

to our readers

Requests for further information should be directed to the individual or laboratory of origin (except for those from Latin America).

Addresses are as follows:

AIR FORCE CAMBRIDGE RESEARCH LABORATORIES
Attn: CRI
Laurence G. Hanscom Field, Bedford, Massachusetts 01731

AEROSPACE RESEARCH LABORATORIES
Attn: ARB
Wright-Patterson Air Force Base, Ohio 45433

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH
Attn: SRGL
Tempo D Building
4th and Independence Avenue, S.W., Washington, D.C. 20333

OFFICE OF RESEARCH ANALYSES
Attn: ORR
Holloman AF Base, New Mexico 88330

Requests for further information from institutions and individuals in Latin America should be addressed to:

LATIN AMERICAN OFFICE AEROSPACE RESEARCH
U. S. Embassy
Rio de Janeiro, Brazil

Detailed documentary reports may be obtained from:

OFFICE OF TECHNICAL SERVICES
U.S. Department of Commerce, Washington, D.C. 20230

DEFENSE DOCUMENTATION CENTER FOR SCIENTIFIC AND TECHNICAL INFORMATION *
Cameron Station, Alexandria, Virginia 22314

* Qualified requestors

GPO 873-263